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Technological Diffusion, Learning and Economic Performance

An Empirical Investigation on an Extended Set of Countries

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Technological diffusion, learning and economic performance: an empirical investigation on an extended set of countries.*

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Abstract:

This paper investigates the effects of technological diffusion and learning by doing, as represented by imports of equipment, on a cross-section of countries. There appears to be substantial evidence for a positive though not constant impact of imported equipment on growth. The structure of the relationship estimated suggests there may be increases in productivity to be gained from learning by importing equipment.

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Introduction

The development of technology and technological spillover have long been considered as one of the principal factors in explaining economic growth across countries. Whether the analysis derives from formal new growth theory context or from the Schumpeterian perspective of evolutionary economics, the conclusions point towards the important role of technology in countries' economic performance.

In some recent new growth theory models (Grossman and Helpman 1991, Romer and Rivera-Batiz 1991), the process of long term growth is thought to be the result of innovating activities. Such activities increase total factor productivity, either by increasing the number of available inputs, or by upgrading product quality, and make increasing returns to scale possible. When these models are analyzed in an open economy setting, since countries are assumed to have specific factor endowments, human capital rich countries will have a comparative advantage to engage in innovating activates, as human capital is the principal production factor in R&D (Grossman and Helpman 1991). Countries that have a comparative disadvantage in this kind of activities will have to engage in some form of catch-up process by learning, imitating and implementing foreign developed technology so as not to lose the productivity and growth gains that come from technological progress.

A necessary element in the process of catching up for low and middle income countries may then be to import, learn and assimilate foreign technology (Grossman and Helpman 1991, Helpman 1993, Barro and Sala-i-Martin 1995). However, high income countries might also benefit extensively from importing technology. For example, if the process of economic development produced lock-in of sector specific knowledge, so that different countries developed sector specific abilities with respect to certain technologies, they would then have to rely on importing other countries' technologies for all the other sectors of the economy. If this were the case, industrialized countries would also depend on foreign technology in order to maintain production on the technological frontier in all sectors.

Empirical analyses of these processes encounter considerable difficulty when defining an adequate variable to proxy technology. Recent studies have attempted to classify technological goods, i.e. goods that embody technology, for example in the form of R&D expenditures (OCDE 1980, 1986, 1990, Guerrieri Milana 1992, US Department of Commerce 1986). De Long and Summers (1991, 1992) explain high returns to equipment investment as the result of productivity gains obtained by introducing new machinery in the production process and by learning by doing. Machinery appears to be quite a good proxy for technological development. On the one hand, in some classifications of technological content, it is found to be a category which presents the highest number of patent innovations produced and used per certain period of time (Wakelin 1995, Pavitt 1987). On the other hand, the machinery sector has often been called the engine of growth because of it makes it possible to produce new and better goods. A the efficient production and implementation of equipment is then the key to productivity and progress in the rest of the economy.

In this sense, machinery is a good that not only embodies technological progress, but also transfers it to goods in production: it can be thought of a sort of "technology carrying" good. For this reason it will be taken to represent an adequate channel for the transfer of technology among countries. The importance of imports of equipment to the international technological transfer process was also stressed in the works of Bloomstrom, Lipsey and Zejan (1992), Romer (1993) and Lee (1994).

The aim of this paper is to perform an empirical analysis on the size and the direction of the effects of foreign technology transfer, as proxied by imports of equipment. The estimates are performed for an extended set of countries. The paper is organized as follows: section I introduces the theoretical framework and presents the model and the data; section II describes the econometric techniques and presents the estimation results; section III briefly draws some conclusions.

Section I

The importance of equipment within the investment aggregate has long been emphasized theoretically and, more recently, has been supported empirically by a series of works by De Long and Summers (1991, 1992). The high returns estimated on this form of investment have been explained as the productivity effects of introducing new machinery, with it new technology, in the production function. Machinery not only embodies technology in the form of patent innovations (Wakelin 1995), but can be thought to represent the new technology actually implemented in the production process. Learning by doing effects may be generated. These would actively increase total factor productivity once equipment is introduced in production.

Trade in machinery would enable technology to be effectively transfered internationally so that countries behind the technological frontier might benefit from new technology, and learning by doing (De Long and Summers 1991, 1992). At the same time, some kind of learning by watching from investment, as discussed in King and Robson 1989, 1993 might enable the importing country to benefit from technological spillovers due to foreign technology.

The model

The estimated equation was derived from a simple new growth model. The aggregate production is a function of labour (L) and human capital (H) and of an increasing availability of intermediate inputs:

$$Y=AL^{\beta}H^{\delta}\sum_{i=1}^{n}x_i^{\alpha} \quad 0<\alpha;\delta,\beta<1 \tag{1}$$

where x_i are intermediate inputs entering the production function, which are assumed in this case to be various types of capital inputs, n is the total number of available inputs. All available inputs are assumed to enter symmetrically the production function and to have the same price. In this case, producers' demand for each intermediate input x_i will be equal to x. Since nx is the total amount of fixed resource embodied in the final good, nx defines K. Taking per worker level of output the equation will be defined by:

$$y=\frac{Y}{L}=AH^{\delta}L^{\beta-1}K^{\alpha}n^{1-\alpha} \tag{2}$$

Taking logs and differentiating over time leads to the following growth expression:

$$\frac{\dot{y}}{y}=\frac{\dot{A}}{A}+\delta\frac{\dot{H}}{H}+(\beta-1)\frac{\dot{L}}{L}+\alpha\frac{\dot{K}}{K}+(1-\alpha)\frac{\dot{n}}{n} \tag{3}$$

Per worker output growth is explained in terms of growth of labour and human and physical capital and in terms of increasing number of intermediate inputs. In this case the increasing availability of various capital goods is proxied by the imports of equipment. Since this variable is included in the investment variable, the investment share will of imported equipment will also be included. In fact, in order to evaluate the impact of the technological transfer, it would be interesting to note the differential effect on productivity of the home produced equipment against imported equipment. This could not be done for because data on total equipment investment for countries were not available. $\dot{A}/A$ is defined as the rate of change of countries' technological level, which is often assumed to be a function of the technological gap. This will be proxied by labour productivity gap with respect to the U.S. The technological gap should be inversely correlated with the growth rate, since the speed of catching up declines as countries approach the steady state rate of growth of the technology leader.

If there is learning by doing and technological spillovers, the combined effect through n, H, and A may be measured by imports of equipment, in it simplest version the equation to be estimated should include:

$$\dot{Y}_{i,t}=C+C_i+C_t+\beta_1 LGAP+\beta_2 IMEQ+\beta_3 INVNEQ+\beta_4 H_0+\beta_5 \Delta H+\beta_6 \Delta L+e_{i,t}$$

Where: lgap represents the per capita income gap, imeq and invneq are defined as the gdp share of equipment imports and investment net of equipment imports, H and L respectfully represent human capital and labour, and H_0 the initial stock of human capital.

Data sources and definitions.

The data set covers 96 countries over the years 1960 to 1990 at five year intervals. However, the regression only considers growth in the period 1965 to 1990, to allow for lagged period explanatory variables. Following Barro (1994), and Barro and Lee (1994), the sample was divided in three periods: 1965-75, 1975-85 and 1985-90.

The data on per capita GDP and investment shares of GDP, used in the estimations were taken from the Summers and Heston (1992) compilation of PWT5. Further data on education and schooling, government consumption, government expenditure on education, and trade related variables were taken from the Barro and Lee (1994) data set. Data on imports of equipment were taken from the UN Yearbook of Trade Statistics and from the UN Yearbook of Trade in Engineering Products and correspond to section 7 of the SITC classification. Finally data on land per person were taken from the World Bank indicators of social development (1993).[1]

The dependent variable was chosen to be growth of real per capita gdp. Data points were available at five year intervals, the growth rates were then calculated over each interval and then averaged over the estimation periods.

Imports of equipment were calculated as a share of gdp and entered at beginning of period values, in order to reduce possible endogeneity problems.

Investment was also calculated as a share of gdp and was entered at the beginning of period values.

Human capital was proxied by two main variables: secondary school enrollment rates and average years of schooling in the population. These educational variables were entered a) as lagged five years before the beginning of period, to account for initial levels of human capital; and b) as the beginning and end of period average growth rate over the previous five years; to proxy the change in the level of human capital in countries.

The gap variable was defined as the logarithm base 10 of the ratio of country's income per capita over income per capita in the US. Total population represents a proxy for labour, for this reason the gap variable was then thought

[1]Detailed data definitions and sources in Appendix A.

to be better expressed in terms of per capita income compared to the US. It was lagged five years, because of its high correlation with the investment variable and it was transformed into logarithms, so that it represented the speed of catch-up, following De Long and Summers (1992).

Finally, regressions were run with a series of additional variables, such as real total government consumption over real gdp, nominal government spending on education over nominal gdp, shocks on the terms of trade, black market premiums, trade dependency ratio as an openness index, and land per person to represent natural resource endowments. This was done to perform a sensitivity analysis, to test against possible alternative variables that may carry the same explanatory power as equipment imports, and also to introduce other proxies for initial conditions. All the variables were entered at the beginning of period values.

Econometric methods and techniques

Initially, the estimation was performed with the whole set of 96 countries[2]. The sample was set up as a panel and a series of pooling tests were performed to allow for fixed time effects and fixed continental effects. In all cases the hypothesis of no time effects was rejected against the alternative of fixed time effects and the hypothesis of no continental effects was rejected against the alternative of fixed continental effects.

In all cases coefficients estimated under this procedure were not considerably different from those obtained by allowing for random two way effects. In most cases, autocorrelation in the structure of time effects was allowed for, while still including fixed continental dummies. This kind of

[2] Country list in Appendix B.

structure was found to have little explanatory power once, lagged explanatory variables were included in the equation (Table 1 eqs. 8 and 9).

The coefficients estimated on the imports of equipment variable including or excluding investment in the regression did not appear to present substantial differences: the low value estimated previously was not due to the differential impact of importing equipment other than that already included in the investment variable. The regression which excluded the investment variable presented a low loss in R^2 (table 1 eq.3), and the size of the coefficient for imports of equipment did not vary considerably: all following regressions were then run by omitting investment.

Sensitivity analysis of the estimation results was performed by including alternative explanatory variables. Government expenditure on education was also considered jointly with total government consumption because the impact of the two variables did not appear to change if one or the other was omitted.

The correlation between the lagged logarithm of the gap variable and the variables representing investment and equipment imports was found to be low.

The estimation was also performed to include imports of equipment at the beginning and end of period average over the previous period, and also the dependent variable at the beginning and end of period average growth rate of the previous period, thus allowing for possible endogeneities
(Table 1 eq. 4 and 6).

The coefficient on equipment imports appears to be efficiently estimated, but rather low if compared with the estimation results of De Long and Summers (1991, 1992) on equipment investment. The coefficient on the lagged equipment imports variable does not appear to change substantially so that the evidence that the coefficient on the beginning of period value is biased due to simultaneity is weak. However, when using equipment imports calculated as beginning and end of period averages over the same periods as the dependent variable, the estimated coefficient to increases with respect to the coefficient estimated coefficient using the beginning of period value (Table 1 eq.7), which suggests there might be bias due to endogeneity when contemporary equipment imports are used.

Table 1[3].

(a) fixed time effects only, allowing for autocorrelation
(b) fixed time and continental effects.
(c) fixed time and continental effects, with autocorrelation in the time effects structure.

	1 (a)	2 (c)	3 (c)	4 (c)	5 (c)	6 (c)	7 (c)	8 (b)	9 (b)
gap	-.004 (.003)	-.005 (.003)	-.008 (.003)	-.005 (.003)	-.004 (.003)	-.006 (.003)	-.006 (.003)	-.009 (.003)	-.005 (.003)
imeq	.063 (.029)	.048 (.031)		.060 (.028)			.050 (.029)	.054 (.028)	.049 (.027)
invs		.026 (.025)	.056 (.025)						
lab	-.19 (.15)	-.26 (.15)	-.18 (.16)	-.29 (.15)	-.26 (.15)	-.30 (.14)	-.17 (.15)	-.10 (.16)	-.19 (.16)
secer12	.001 (.025)								
schyp	.003 (.001)	.0025 (.001)	.0027 (.001)	.003 (.001)	.002 (.001)	.003 (.001)	.003 (.001)	.0028 (.002)	
secer									.014 (.010)
land	-.070 (.036)		-.048 (.025)	-.041 (.036)	-.042 (.036)	-.038 (.035)	-.017 (.036)		
lagimeq					.021 (.032)				
curimeq						.105 (.030)			
laggdp							.165 (.076)		
tgovc								-.129 (.064)	-.110 (.027)
goved								.056 (.137)	.131 (.138)

* standard errors in parenthesis.

[3] All regressions contain an unreported constant.

Table 1. (cont.)

	1 (b)	2 (b)	3 (b)	4 (b)	5 (b)	6 (b)	7 (c)	8 (c)	9 (c)
gap	-.002 (.002)	-.009 (.002)	-.009 (.002)	-.006 (.003)	-.009 (.002)	-.010 (.003)	-.008 (.003)	-.004 (.003)	-.001 (.002)
imeq	.048 (.026)	.050 (.029)	.054 (.028)	.063 (.038)					.047 (.028)
schyp		.003 (.001)	.002 (.001)	.002 (.001)	.002 (.001)	.002 (.001)	.0027 (.001)	.002 (.001)	
lab		-.11 (.17)	-.17 (.17)	-.11 (.15)	.006 (.176)		-.18 (.16)	-.26 (.15)	-.18 (.16)
invs						.029 (.027)			
goved	.162 (.132)								
tgovc	-.111 (.026)	-.133 (.028)	-.124 (.026)	-.119 (.024)	-.116 (.027)	-.166 (.027)			
tts			-.015 (.032)						
bmp		-.002 (.001)							
open				-.004 (.007)	.007 (.007)	.006 (.007)			
laginvs							.056 (.025)		
land							-.048 (.025)	-.039 (.036)	-.002 (.039)
imeq12								.059 (.035)	
secer12									-.006 (0.18)
R_2 AR_2	29 25	32 28	32 27	37 33	29 25	30 26	30 23	26 23	23 19

The coefficients estimated for investment do not appear to be very different from those obtained by Barro (1994, 1995). As in the case of equipment imports, some regressions were run using lagged period averages of investment shares (Table 1 cont., column 8), but the coefficients were not considerably different from those estimated using the beginning of period values so that there appears to be weak evidence of simultaneity problems when using the beginning of period values.

The negative coefficients on the land variable support the forecasts of the Grossman and Helpman model of open economy growth in the case in which a natural resource abundant country trades with a human capital abundant country.

In a second analysis, coefficients for equipment imports were estimated separately for each period, but only some continental dummies were included, in order not to lose too many degrees of freedom. In this case, there appears to be an increasing trend in the size of the effects of equipment imports, as the strong technological development of the last two decades would lead one to expect.

Table 2.

Period estimation

(d) continental dummies[4]

	1965 - 1975			1975 - 1985			1985 - 1990		
lap	-.003 (.005)	-.004 (.004)	-.002 (.004)	-.010 (.004)	-.001 (.004)	-.007 (.005)	-.010 (.006)	-.001 (.007)	-.006 (.007)
imeq	.040 (.039)	.024 (.036)	-.017 (.042)	.078 (.039)	.073 (.042)	.053 (.045)	.103 (.076)	.089 (.078)	.099 (.084)
schyp	.9E-03 (.001)		-9.E-03 (.001)	.003 (.001)		.003 (.001)	.004 (.002)		.004 (.002)
lab	-.060 (.22)	-.075 (.22)	.028 (.22)	-.32 (.20)	-.45 (.21)	-.21 (.21)	-.47 (.34)	-.56 (.35)	-.37 (.37)
tgovc	-.105 (.037)	-.084 (.037)		-.131 (.033)	-.122 (.039)		-.157 (.064)	-.147 (.077)	
goved		.214 (.281)			.180 (.214)			.139 (.252)	
inks			.100 (.035)			.020 (.039)			.010 (061)
R^2 AR^2	.16 .06	.12 .02	.16 .06	.41 .34	.32 .25	29 21	.27 .18	.23 .14	.21 .11

* as for Table 1.

A possible problem arising in the estimates is that the impact of equipment imports is only important for countries that already have a developed production structure, and that the sluggish performance of very low income countries is what causes the small effect estimated on imported equipment.

In order to control further for specific effects due to initial income level, the sample was stratified according to per capita income in 1960. This was done by identifying the richest 20% and the poorest 30% of countries, and then the

[4]Continental dummies included are: africa, latin america and asia

regressions were run on each subsample. In all cases fixed time and continent effects were tested and included since the null of no fixed time and continent effects was rejected.

Table 3*. Income stratification.

(f) continental dummies[5] and time effects
(g) continental dummies and time effects allowing for autocorrelation in time effects

Table 3a.
High Income Countries

	1 (g)	2 (g)	3 (g)	4 (f)	5 (g)
gap	-.008 (.008)	-.006 (.008)	-.005 (.005	-.008 (.009)	-.007 (.008)
imeq	.006 (.035)	.004 (.034)	.017 (.037)	.009 (.036)	.004 (.046)
schyp	.001 (.001)	.001 (.001)	.7E-03 (.001)		.5E-03 (.001)
lab	-.30 (.22)	-.37 (.22)	-.39 (.22)	-.40 (.20)	-.33 (.23)
land			.006 (.024)		
tgovc				-.027 (.060)	
goved				.202 (.167)	
invs		.075 (.034)	.082 (.037)	.096 (.030)	.069 (.039)
open					.002 (.010)
R^2 AR^2	52 44	56 48	49 38	50 48	.55 .46

[5] For low income countries the latin american dummy was excluded

Table 3b.

Middle Income Countries

	1 (g)	2 (g)	3 (f)	4 (g)	5 (g)
gap	-.003 (.005)	.6E-03 (.006)	.001 (.006)	.003 (.005)	.001 (.005)
imeq	.068 (.039)	.068 (.044)	.090 (.041)	.079 (.070)	
schyp	.004 (.001)	.004 (.001)		.003 (.007)	.003 (.001)
lab	-.27 (.23)	-.28 (.25)	-.42 (.24)	-.31 (.22)	-.35 (.21)
land	-.39 (.13)	-.401 (.13)	-.217 (.136)	-.39 (.13)	-.38 (.12)
invs		.001 (.039)			.029 (.036)
tgovc			-.123 (.046)		
goved			.103 (.23)		
open				-.006 (.013)	.005 (.009)
R^2 AR^2	42 37	42 36	34 28	47 42	50 45

Table 3c.

Low Income Countries

	1 (g)	2 (f)	3 (f)	4 (f)	5 (f)
gap	.010 (.008)	.013 (.008)	.008 (.009)	-.016 (.012)	-.014 (.013)
imeq	.008 (.046)	-.017 (.066)	-.007 (.068)		
schyp				.016 (.046)	.016 (.046)
lab	.40 (.41)	.37 (.42)	.32 (.40)	.83 (.57)	.91 (.59)
land	.22 (.27)	.19 (.27)	.077 (.036)	.157 (.046)	.156 (.045)
invs		.004 (.059)		-.124 (.082)	-.107 (.087)
tgovc			-.055 (.051)		
goved			.457 (.318)		
open					-.029 (.037)
R2 AR2	47 37	36 24	41 28	44 32	44 31

* as for Table 1.

There appears to be a considerable difference in the average level of the coefficients on equipment imports estimated for middle income and high income countries. However, since both the estimated coefficients present a considerable dispersion, the coefficients of equipment imports are not statistically significantly different across different income countries. An interesting observation is the fact that high and low income countries do no have a statistically significant coefficient, but middle income countries have a significant coefficient. This is evidence in favour of the hypothesis that the impact of equipment imports is stronger for middle income countries than for high income countries, as would be expected if such countries were to import all their equipment from abroad. The variable should then bear the dual productivity effect produced by equipment investment in capital accumulation and by international technological transfer.

If the most important effect of machinery imports does not rely simply on capital accumulation process, but mainly in the technological diffusion effect and in learning by watching processes, then the structure of the effects could present a more complicated functional form. The process of technological diffusion has often been modeled as a learning curve process, i.e. a logistic curve. The reason for this is that it presents a behavior similar to that observed in studies of epidemics. Assuming that there is a certain given amount of knowledge, technology, in a system, individuals can assimilate such knowledge (knowledge can be transferred), and the rate at which each individual can something new depends on the amount of effort put in, on the technical features of the original technology and on the difference between the amount of knowledge he has already gained and that to which he is new. This presents a dynamic structure similar to that of a logistic curve. At first the rate of knowledge accumulation is slow because of the gap between known and unknown technologies. Learning speeds up as a kind of threshold value is reached, more information is successfully assimilated, and, finally, goes back to being a slow process once most of the technology has been learned. A couple of articles by King and Robson (1989, 1993) develop a "technological progress function" that describes productivity increases obtained from learning by watching as a function of total investment. They assume that the learning by watching effects is a logistic function of total investment.

In this analysis, imports of machinery represent the means of the learning process, and so determines the rate of technological diffusion. At low amounts of imported machinery, the learning process may be slow, so marginal productivity effects will be low. Learning will grow faster at levels of imported machinery above the threshold. This will show up in a greater impact of machinery on overall growth. However, the learning process will slow down again once levels of machinery reach an upper bound, when the economy will have acquired most existing knowledge. This will reduce the productivity effects of further machinery imports.

If this were the case, estimating the relationship in linear form would lead to a substantial underestimation of the transfer effect, because the estimate would only represent the average outcome of the three phases.

In order to test the hypothesis that the structure of the impact of machinery imports follows a learning effect type of functional form, the general sample was stratified according to the ratio of imported equipment over gdp. The sample was cut at a series of alternative levels. The fit of the estimated equation increased considerably. The tests for the null hypothesis of no time effects versus the alternative of fixed time effects led clearly to acceptance of the null. Since evidence for fixed time effects was weak, a simple pooled panel estimation is presented, along with some regressions including continental dummies. A series of alternative cut-off intervals were tested: the fit was maximized for a particular cut-off interval and then decreased for any alternative. In this set of estimates, the coefficients estimated on the import of machinery variable increase significantly, and so did the R^2 of the model. Further evidence of a logistic structure in the relation came from varying the dimension of the optimal cut-off interval: for increasingly greater cut-off intervals the estimated coefficient decreased, which would be the expectation if the estimates of the slope of a logistic function were performed at increasing intervals (fig 1, Table 4).

Table 4*

Interval estimation

(a) ols
(b) ols with continental dummies
(c) ols with continental dummies excluding low income countries

cut-off interval	0.05 < imeq imeq < 0.18 (a)	0.05 < imeq imeq < 0.18) (b)	0.05 < imeq imeq < 0.18 (c)	0.02 < imeq imeq < 0.24 (a)
imeq	.220 (.061)	.170 (.061)	.190 (.063)	.096 (.036)
lap	-.010 (.004)	-.010 (.004)	-.013 (.004)	-.007 (.003)
lab	-.210 (.170)	-.540 (.180)	-.651 (.172)	-.296 (.141)
schyp	.002 (.001)	.002 (.001)	.003 (.031)	.002 (.9E-3)
tgovc	-.193 (.033)	-.204 (.032)	-.221 (.031)	-.172 (.026)
R^2 AR^2	39 36	47 43	54 51	25 23

* as for Table 1.

In this case coefficients estimated on the equipment imports variable are considerably greater than coefficients in the other estimates reported above; the are relatively stable and efficient. Further, the dimensions of such coefficients are comparable to those obtained by De Long and Summers (1991, 1992) and are significantly greater than those estimated by Barro (1991, 1994, 1995) for total investment.

Conclusions

The results of the estimations indicate that there is little evidence for a strong positive linear relation between imports of equipment and economic growth. However, the estimated impact of investment is not significantly different from that reported in previous studies which use a panel of the same structure.

In general, imports of equipment do not appear to be a good proxy for overall equipment investment, in particular for developing countries, since the dimensions of the estimated relations on the general and on the income stratified samples are significantly lower than those reported by De Long and Summers (1991, 1992) in their work on the impact of equipment investment. Also their results might be biased upwards since some evidence for an increase in the size of the coefficients was found when equipment imports were entered as beginning and end of period average over the same period of the depended variable.

However, as reported in Table 3b, there appears to be some evidence supporting the expectation that equipment imports will have a greater impact on middle income developing countries than on developed countries. This would occur both because equipment imports represent higher shares of equipment investment and because equipment imports would act as a channel of technological transfer.

The hypothesis concerning the effects of technological diffusion and learning by watching through equipment imports appears to gain substantial support (Table 4). This implies a logistic structure for the effects of equipment imports on growth. In the regressions, where countries were included if the equipment imports to gdp ratio fell in a given interval, the coefficient was smaller when longer intervals were used. This is the expected result if the effect is a logistic function of imported equipment. This procedure leads to a considerably better fit in the growth equation than any other preceding regression. Finally, estimated coefficients are of dimensions comparable to those obtained by De Long and Summers in their study.

In conclusion, there appears to be substantial evidence for positive effects on growth of equipment imports. The evidence found on the structure of the impact, suggests that the most important effect of equipment imports is due to international technology transfer and to learning by watching effects. This process has been found to bear a learning-type structure, for which the functional form of the impact follows a logistic function. Therefore the dimensions of the marginal impact of equipment imports are not constant along for different ratios of equipment investment to gdp. Only along a certain interval is the impact of equipment imports strong on growth, outside this interval the effects are limited. It appears that if very little equipment is imported, countries are locked in a low growth structure. If imported equipment represents a substantial share of output, beneficial effects will tend to die out, maybe because there is a limit to how quickly technology can be assimilated. In fact this downturn in the effects of imported equipment may be endogenous to economic development, since at high levels of output equipment would tend to be mostly home produced.

Since I had was no access to data on total investment in equipment, it was impossible to discriminate the impact of imported equipment and that of home produced equipment. This would have been important in evaluating the magnitude of the technological diffusion effect alone especially in the case of countries that have developed an engineering sector which is efficient and competitive.

Finally, if the effects of the technological transfer process in the form of equipment imports were really to follow a logistic structure, then equipment imports could well be an important factor in the catch-up process, but the key to long run growth would more probably depend on the countries ability to develop an own engineering sector with R&D and innovation activities.

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Appendix A.

Variable names and sources:

RGDP: Gross Domestic Product at 1985 prices; average over the periods (1965-1975, 1975-1985, 1985-1990). Source: SH PWT5.

GOVED:Ratio of total nominal government expenditure on education to nominal gdp; average over the periods (1960-70, 1970-1980, 1980-1985); Source: Barro and Lee (1994).

TGOVC:Ratio of real government "Consumption" expenditure to real

GDP;average over the periods (1960-70, 1970-1980, 1980-1985);Source: SH PWT5.

IMEQ: Imports of machinery and transport equipment (SITC 7), over GDP; beginning of period values (1965,1975,1985). Source: UN Yearbook of International trade and SH PWT5.

IMEQ12: Imports of machinery and transport equipment (SITC 7), over GDP; average over the periods (1960-70, 1970-1980, 1980-1985). Source: UN Yearbook of International trade and SH PWT5.

LAGIMEQ: Imports of machinery and transport equipment (SITC 7), over GDP; average over the periods (1960-1965, 1965-1970, 1970-1980). Source: UN Yearbook of International trade and SH PWT5.

CURIMEQ: Imports of machinery and transport equipment (SITC 7), over GDP; average over the periods (1965-1975, 1975-1985, 1985-1990). Source: UN Yearbook of International trade and SH PWT5.

INVS: Investment share of GDP; beginning of period values (1965, 1975, 1985). Source SH PWT5.

LAGINVS:Investment share of GDP; average over the periods (1960-1965, 1965-1970, 1970-1980).Source SH PWT5.

GAP: Logarithm in base 10 of the per capita income gap with respect to the U.S., (y_c/y_{us}); lagged beginning of period values (1960, 1970, 1980). Source: SH PWT5.

LAND: Total Area/ Total Population; beginning of period values (1965, 1975, 1985). Source: Indicators of Social Development (World Bank).

OPEN: (Total Imports + Total Exports) / RGDP; average over the periods (1960-70, 1970-1980, 1980-1985). Source: SH PWT5.

SCHYP: Average number of Schooling years in the population;beginning of period values (1965, 1975, 1985). Source: Barro and Lee (1994).

SECER: Secondary School Enrollment Rates;lagged beginning of period values (1960, 1970, 1980) Source: World Bank Indicators of Social Development and UNESCO yearbook

SECER12: Growth of secondary school enrollment rates;average over the periods (1960-70, 1970-1980, 1980-1985) source: World Bank Indicators of Social Development and UNESCO yearbook.

TTS: Terms of Trade shock (growth rate of export prices minus growth rate of import prices; average over the periods (1960-70, 1970-1980, 1980-1985); Source: Barro and Lee (1994).

BMP: Black market premium; average over the periods (1960-70, 1970-1980, 1980-1985); Source: Barro and Lee (1994).
LAB: Growth of active population; average over the periods (1960-70, 1970-1980, 1980-1985) Source: World Bank Indicators of Social Development and ILO yearbook.

Appendix B

Countries in the Sample (edited from SH PWT5)

The countries are ordered alphabetically within their continent code (CCODE) listed below. The three letter code is the World Bank country code.

CCODE=1 AFRICA
2 CENTRAL & NORTH AMERICA
2s SOUTH AMERICA
3 ASIA
4 EUROPE
5 OCEANIA

1	ALGERIA	1	DZA
4	BOTSWANA	1	BWA
7	CAMEROON	1	CMR
9	CENTRAL AFR.R.	1	CAF
12	CONGO	1	COG
13	EGYPT	1	EGY
14	ETHIOPIA	1	ETH
17	GHANA	1	GHA
20	IVORY COAST	1	CIV
21	KENYA	1	KEN
22	LESOTHO	1	LSO
24	MADAGASCAR	1	MDG
25	MALAWI	1	MWI
26	MALI	1	MLI
28	MAURITIUS	1	MUS
29	MOROCCO	1	MAR
32	NIGERIA	1	NGA
33	RWANDA	1	RWA
34	SENEGAL	1	SEN
35	SEYCHELLES	1	SYC
36	SIERRA LEONE	1	SLE
38	SOUTH AFRICA	1	ZAF
40	SWAZILAND	1	SWZ
41	TANZANIA	1	TZA
42	TOGO	1	TGO
43	TUNISIA	1	TUN
44	UGANDA	1	UGA

45	ZAIRE	1	ZAR
46	ZAMBIA	1	ZMB
47	ZIMBABWE	1	ZWE
49	BARBADOS	2	BRB
50	CANADA	2	CAN
51	COSTA RICA	2	CRI
53	DOMINICAN REP.	2	DOM
54	EL SALVADOR	2	SLV
56	GUATEMALA	2	GTM
57	HAITI	2	HTI
58	HONDURAS	2	HND
59	JAMAICA	2	JAM
60	MEXICO	2	MEX
61	NICARAGUA	2	NIC
65	TRINIDAD&TOBAGO	2	TTO
66	U.S.A.	2	USA
67	ARGENTINA	2s	ARG
68	BOLIVIA	2s	BOL
69	BRAZIL	2s	BRA
70	CHILE	2s	CHL
71	COLOMBIA	2s	COL
72	ECUADOR	2s	ECU
73	GUYANA	2s	GUY
74	PARAGUAY	2s	PRY
75	PERU	2s	PER
77	URUGUAY	2s	URY
78	VENEZUELA	2s	VEN
82	BURMA(Myanmar)	3	BUR
84	HONG KONG	3	HKG
85	INDIA	3	IND
86	INDONESIA	3	IDN
87	IRAN	3	IRN
88	IRAQ	3	IRQ
89	ISRAEL	3	ISR
90	JAPAN	3	JPN
91	JORDAN	3	JOR
92	KOREA,SOUTH(R)	3	KOR
94	MALAYSIA	3	MYS
95	NEPAL	3	NPL
97	PAKISTAN	3	PAK
98	PHILIPPINES	3	PHL

100	SINGAPORE	3	SGP
101	SRI LANKA	3	LKA
102	SYRIA	3	SYR
103	TAIWAN	3	OAN
104	THAILAND	3	THA
107	AUSTRIA	4	AUT
108	BELGIUM	4	BEL
109	CYPRUS	4	CYP
110	DENMARK	4	DNK
111	FINLAND	4	FIN
112	FRANCE	4	FRA
113	GERMANY, WEST	4	DEU
114	GREECE	4	GRC
116	ICELAND	4	ISL
117	IRELAND	4	IRL
118	ITALY	4	ITA
121	NETHERLANDS	4	NLD
122	NORWAY	4	NOR
124	PORTUGAL	4	PRT
125	SPAIN	4	ESP
126	SWEDEN	4	SWE
127	SWITZERLAND	4	CHE
128	TURKEY	4	TUR
129	U.K.	4	GBR
131	AUSTRALIA	5	AUS
132	FIJI	5	FJI
133	NEW ZEALAND	5	NZL
134	PAPUA N.GUINEA	5	PNG

Years in the sample:
1960, 1965, 1970, 1975, 1980, 1985, 1989.

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